# PATENT ABSTRACTS OF JAPAN

(11)Publication number : 2000-087117
(43)Date of publication of application : 28.03.2000

(51)Int.Cl. B22F 7/08
F16K 31/06

(21)Application number : 10-261866
(22)Date of filing : 16.09.1998

(71)Applicant : HITACHI POWDERED METALS CO LTD
(72)Inventor : ASAKA KAZUO

## (54) METHOD FOR JOINING VALVE SHAFT OF SOLENOID VALVE TO SINTERED MOVABLE IRON CORE

(57)Abstract:
PROBLEM TO BE SOLVED: To perform the sintering of a green compact and its joining to a valve shaft by a single process, to reduce the size and weight of a movable iron core, and to improve the responsiveness of a solenoid valve by compacting a powder of ferromagnetic material excellent in soft magnetic properties or a powder mixture of equivalent composition into the required shape and size of a movable iron core, fitting the resultant green compact in the prescribed position of a valve shaft, and carrying out sintering.
SOLUTION: It is preferable that the material of a sintered movable iron core is composed of any of pure iron, Fe-P-alloy, Fe-Si alloy, Fe-Si-P alloy, Permalloy (R) alloy, Permendur (R) alloy, and electrical stainless steel materials, and further, as for a fit tolerance between the inside diameter of a green compact and the valve shaft, running fit of ≤5 $\mu$m clearance or close fit of ≤60 $\mu$m interference is preferred. Moreover, the valve shaft is composed preferably of a non-magnetic material of ≤100 magnetic permeability. Because no allowance for machining is necessary for attachment to the valve shaft in this method, the movable iron core can be reduced in size and weight. Further, the amount of expansion of the green compact, in the high temperature region where sintering proceeds, is smaller than that of the valve shaft composed of melted material, and the valve shaft can be held tight by the green compact.

LEGAL STATUS

| | |
|---|---|
| [Date of request for examination] | 09.08.2001 |
| [Date of sending the examiner's decision of rejection] | 30.09.2003 |
| [Kind of final disposal of application other than the examiner's decision of rejection or application converted registration] | |
| [Date of final disposal for application] | |
| [Patent number] | |
| [Date of registration] | |
| [Number of appeal against examiner's decision of rejection] | 2003-20979 |
| [Date of requesting appeal against examiner's decision of rejection] | 29.10.2003 |
| [Date of extinction of right] | |

(19)日本国特許庁（JP）　(12) 公開特許公報（A）　(11)特許出願公開番号
特開2000－87117
（P2000－87117A）
(43)公開日 平成12年3月28日(2000.3.28)

| (51)Int.Cl.⁷ | 識別記号 | F I | | テーマコード(参考) |
| --- | --- | --- | --- | --- |
| B22F 7/08 | | B22F 7/08 | E | 3H106 |
| F16K 31/06 | 305 | F16K 31/06 | 305J | 4K018 |

審査請求 未請求 請求項の数4 OL （全 3 頁）

(21)出願番号 特願平10－261866
(22)出願日 平成10年9月16日(1998.9.16)
(71)出願人 000233572
日立粉末冶金株式会社
千葉県松戸市稔台520番地
(72)発明者 浅香 一夫
千葉県松戸市稔台687
(74)代理人 100083806
弁理士 三好 秀和
Fターム(参考) 3H106 EE48 JJ03 JJ05 KK03 KK17
4K018 AA24 AA25 AA26 CA12 CA19
DA11 KA45

(54)【発明の名称】 電磁弁における弁軸と焼結可動鉄心の接合方法

(57)【要約】
【課題】 流体の制御に用いられているソレノイドで作動する電磁弁のシャフト（弁軸）に可動鉄心を取り付ける際、従来は溶製材から切削加工などで作製した鉄心をかしめその他の塑性加工で弁軸に固定しているが、鉄心の材質が塑性変形可能なものに限定されたり、加工代を要し小型化できない等の問題があった。
【解決手段】 所要組成の金属粉を可動鉄心の形状に圧縮成形し、この圧粉体を弁軸の所定の位置に嵌め込んで一体に焼結する。可動鉄心の焼結と弁軸への接合が1工程で完了するためコストが低く、加工代が不要なので小型・軽量化され、応答性も向上する。

【特許請求の範囲】

【請求項１】　軟質磁気特性の優れた強磁性材の粉末またはその組成の混合粉を可動鉄心の所要の形状寸法に圧縮成形し、この圧粉体を弁軸の所定の位置に嵌め込んで焼結することにより圧粉体の焼結と弁軸への接合を一工程で完了することを特徴とする、電磁弁における弁軸と焼結可動鉄心の接合方法。

【請求項２】　焼結可動鉄心の材質が、純鉄，Ｆｅ－Ｐ系合金，Ｆｅ－Ｓｉ系合金，Ｆｅ－Ｓｉ－Ｐ系合金，パーマロイ系合金，パーメンジュール系合金，電磁ステンレス材料の何れかである請求項１に記載の電磁弁における弁軸と焼結可動鉄心の接合方法。

【請求項３】　圧粉体の内径と弁軸との嵌め合い寸法差が隙間５μｍ以下の通り嵌めもしくは締め代６０μｍ以内の締まり嵌めである、請求項１または請求項２に記載の電磁弁における弁軸と焼結可動鉄心の接合方法。

【請求項４】　弁軸が透磁率１００以下の非磁性材である、請求項１，請求項２または請求項３に記載の電磁弁における弁軸と焼結可動鉄心の接合方法。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】この発明は油圧ポンプ、自動車エンジンの燃料噴射装置その他流体の制御用に広く用いられているソレノイドで作動する電磁弁に関し、特に電磁弁のシャフトに焼結合金の可動鉄心を一体に接合する方法に関するものである。

【０００２】

【従来の技術】電磁弁のシャフト（弁軸）は例えばステンレス鋼ＳＵＳ３０４などの非磁性材が用いられ、その一端に弁座と離接する弁体を、他方の端部ないしその手前に通常円筒状の可動鉄心を備え、ソレノイドコイルに電気パルスが印加されると可動鉄心が移動して弁を開く形式が一般的である。なお組み立ての都合その他から弁軸を弁体と可動鉄心の中間で分割し、弁体側の弁軸を可動鉄心側の弁軸が押して動かす形式もあるが、この明細書における弁軸は両方の場合を含んでいる。

【０００３】

【発明が解決しようとする課題】従来、弁軸への可動鉄心の取り付けには圧入、かしめ、あるいは何等かの塑性加工手段が用いられている。従って可動鉄心はその材質が塑性変形可能なものに限定されること，内径の仕上げに高い寸法精度を必要としコスト高になること，塑性加工を施す上である程度の大きさの加工代を要するため小形軽量化に限界があることなど、鉄心の材質、形状、製造工程などに種々の制約があった。そこでこの発明の目的は、可動鉄心の材質その他の制約を受けずに、可動鉄心を弁軸に一体接合するための安価で量産に適する方法を提供することにある。

【０００４】

【課題を解決するための手段】この発明は、軟質磁気特性が良好で可動鉄心に適する強磁性材料の粉末またはその組成の混合粉を可動鉄心の所要の形状寸法に圧縮成形し、この圧粉体を弁軸の所定の位置に嵌め込んで焼結することにより、圧粉体の焼結と弁軸への接合を１工程で完了することを骨子とするものである。この場合用途に適う強磁性材料としては純鉄、Ｆｅ－Ｐ系，Ｆｅ－Ｓｉ系，Ｆｅ－Ｓｉ－Ｐ系，パーマロイ系，パーメンジュール系合金、および例えばＳＵＳ４１０などの電磁ステンレス材料がある。また弁軸の材料はその透磁率が１００以下であることが好ましい。この方法では弁軸への取り付けに加工代を要しないので、その分可動鉄心を小形軽量化することができる。

【０００５】弁軸に可動鉄心（圧粉体）を嵌め合わせて焼結接合する場合、得られる部品が高い接合強度を持つためには単なる機械的な焼き嵌めだけでなく、両部材の接合面が十分に密着した状態での焼結によって合金成分の固相拡散による接合を図る必要がある。そしてこの点については、純鉄以下の前記の材料は全て、後に説明するように焼結が進行する高温域（鉄系焼結合金では略８００℃以上）における寸法変化量（膨脹量）が溶製材の弁軸よりも小さく、圧粉体が弁軸を締め付けた状態で焼結が進行するので極めて好都合である。

【０００６】また両部材を嵌め合わせる際の嵌め合い寸法差（圧粉体の孔の内径寸法と弁軸の外径寸法との差）も重要であって、弁軸の方を太め（締まり嵌め）に設定して圧粉体の孔に圧入するのが好ましく、締め代は大きいほど、両者の密着度が高くなる。但し強度が低い圧粉体の引っ張り応力による破損を避けるため、締め代を好ましくは３０μｍ以内，多くとも６０μｍ以内に止める必要がある。通り嵌めを選ぶ場合でも、隙間は小さいほどよく、５μｍ以下に止めるべきである。

【０００７】

【発明の実施の形態】先ず弁軸材にステンレス鋼（ＳＵＳ３０４）を、可動鉄心材にＦｅ－０．６Ｐの圧粉体（圧粉密度７．０ｇ／ｃｍ$^3$）を用いる場合について、それぞれの加熱による熱膨張の状態を説明する。測定条件はＳＵＳ３０４は真空中で，圧粉体は窒素ガス中で、それぞれ毎分１０℃の速度で１１３０℃まで昇温させ、２０分間保持したのち、同じ速度で降温させている。なおこの明細書中の組成等に関する％は、特に断らない限り重量％である。

【０００８】ＳＵＳ３０４は室温で既にオーステナイト相を呈しているので、加熱・冷却に伴う同素変態は生じない。単なる熱による寸法変化であって温度の昇降につれて一様な膨脹・収縮を示し、室温に戻れば、寸法も元の寸法に戻る。これに対してＦｅ－０．６Ｐ圧粉体の場合は、昇温過程で同素変態（α－γ変態に伴う収縮）および熱による寸法変化を示すことは溶製材の場合と同様であるが、焼結合金に特有の現象として圧粉体からの焼結過程で粉末粒子の隙間の気孔化～気孔の消失による緻

密化（収縮）を生じ、これらの収縮が熱による膨脹量を減殺する。この結果、拡散接合が進行する略８００℃以上の高温域における圧粉体の熱膨張量はＳＵＳ３０４より遥かに小さくなり、従って両者を嵌め合わせて焼結した場合、可動鉄心を弁軸に密着させた状態での焼結が確実に行なわれる。

【０００９】次に、同じく可動鉄心に適するパーマロイ（Ｆｅ－４７Ｎｉ）の圧粉体（圧粉密度７．１ｇ／ｃｍ$^3$）について、真空中で毎分１０℃の速度で１２００℃まで昇温させ、２０分間保持したのち同じ速度で常温に戻した場合の熱膨張の状態をＳＵＳ３０４と比較して説明する。

【００１０】パーマロイ圧粉体は昇温過程の５５０℃付近までは緩やかに膨脹し、その後は膨脹の勾配が幾分大きくなるが、ＳＵＳ３０４よりは膨脹量が常に小さい。温度が１１７０℃以上では、焼結による収縮が観測され、この収縮は焼結温度の保持段階でも続く。そして室温に戻った段階では、ＳＵＳ３０４は寸法も元の寸法に戻るのに対して、パーマロイ焼結体はＦｅ－０．６Ｐの場合と同じく、加熱前の圧粉体よりも収縮している。

【００１１】従って、粉末冶金法により前記適宜の強磁性材料からなる可動鉄心を圧縮成形し、その圧粉体と非磁性材の弁軸とを嵌め合わせて焼結すれば、圧粉体が弁軸を締め付けた状態で焼結が進行し、両者を強固に一体化することができる。

【００１２】（実施例１）　先ず可動鉄心用として、組成がＦｅ－０．６Ｐの円筒状圧粉体（内径４ｍｍ，外径１０ｍｍ，長さ１２ｍｍ，圧粉密度７．０ｇ／ｃｍ$^3$）を、粉末潤滑剤にアクラワックス（商品名）０．５％を用いて作製した。この円筒の外周には流体の通路として縦方向に数条の溝が設けてあるが、そのことはこの発明の要旨ではない。一方、弁軸には非磁性のステンレス鋼ＳＵＳ３０４を用い、直径４ｍｍの弁軸を作製した。次に圧粉体を締め代２０μｍの圧入により弁軸の所定の位置まで嵌め込み、分解アンモニアガス雰囲気中１２００℃で６０分間焼結して可動鉄心の焼結と弁軸への接合を１工程で行なった。



【００１３】この製品について、可動鉄心を固定しておいて弁軸を押し出す破壊試験をしたところ、接合面が破壊する前に、負荷が３５０ｋｇに達した時点で弁軸の変形を生じた。これは、弁軸の圧縮降伏強さよりも両部材の接合強度が優ったためで、電磁弁の部品として十分な接合が達成されたと評価される。ちなみに従来は弁軸の外周に設けた環状溝に可動鉄心をかしめ付けているが、その際の規格が耐負荷１８０ｋｇであるから、この発明の方法は遥かに超えていることになる。

【００１４】（実施例２）　弁軸は実施例１の場合と同一で、可動鉄心用の圧粉体の材質をパーマロイ（Ｆｅ－４７Ｎｉ；圧粉密度７．１ｇ／ｃｍ$^3$）に変更した。両者を締め代２０μｍの圧入により嵌め合わせて真空中１２００℃で６０分間焼結し、得られた製品の強度を実施例１の場合と同様にして測定したところ、その結果は実施例１の場合と同様であった。従ってこれも、電磁弁の部品として十分な接合に達していると評価される。

【００１５】

【発明の効果】以上に詳述したように、溶製材から形成した可動鉄心を塑性加工などで弁軸に固定する従来の方法とは異なり、焼結合金を用いるこの発明によれば可動鉄心を従来より小形軽量化することができ、電磁弁の応答性が改善される。さらに可動鉄心の焼結と弁軸への接合が１工程で完了するので、経済的にも優れている。

* NOTICES *



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## CLAIMS

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[Claim(s)]
[Claim 1] The junction approach of a valve stem and a sintering moving core in a solenoid valve which presses into the necessary geometry of a moving core the powder of the ferromagnetic material which was excellent in elasticity magnetic properties, or the mixed powder of that presentation, and is characterized by completing sintering of a green compact, and junction to a valve stem at one process by inserting this green compact in the position of a valve stem, and sintering it.
[Claim 2] the quality of the material of a sintering moving core -- pure iron, a Fe-P system alloy, a Fe-Si system alloy, a Fe-Si-P system alloy, a permalloy system alloy, the Permendur system alloy, and electromagnetism -- the junction approach of the valve stem in the solenoid valve according to claim 1 which it is in any of a stainless steel ingredient, and a sintering moving core.
[Claim 3] It inserts each other in, it inserts in as [ of the bore of a green compact, and a valve stem ] variation of tolerance is 5 micrometers or less of clearances, or it is the junction approach of of the valve stem [ in / it is closed, inserts in and comes out and / a certain solenoid valve according to claim 1 or 2 ] and sintering moving core of less than 60 micrometers of interferences.
[Claim 4] The junction approach of a valve stem and a sintering moving core in claim 1 whose valve stem is with a permeability of 100 or less nonmagnetic material, and a solenoid valve according to claim 2 or 3.

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[Translation done.]

## DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention relates to the approach of joining the moving core of a sintered alloy to especially the shaft of a solenoid valve at one about the solenoid valve which operates by the solenoid widely used for control of a hydraulic pump and the other fluids [ a fuel injection equipment and ] of an automobile engine.
[0002]
[Description of the Prior Art] The shaft (valve stem) of a solenoid valve has the common format of nonmagnetic material, such as stainless steel SUS304, being used, a moving core moving if the other-end section thru/or its this side are usually equipped with a cylinder-like moving core and an electric pulse is impressed to a solenoid coil in the valve element which carries out disjunction to a valve seat at the end, and opening a valve. In addition, a valve stem is divided from the convenience and others of an assembly in the middle of a valve element and a moving core, and although there is also a format that the valve stem by the side of a moving core pushes and moves the valve stem by the side of a valve element, the valve stem in this specification includes both cases.
[0003]
[Problem(s) to be Solved by the Invention] Conventionally, press fit, the caulking, or a certain plastic-working means is used for installation of the moving core to a valve stem. Therefore, the moving core had various constraint in the quality of the materials of an iron core -- in order to require the machining allowance of the magnitude of extent which it is when performing being limited to what can deform plastically the quality of the material, needing close dimensional accuracy for finishing of a bore, and becoming cost quantity, and plastic working, a limitation is in small lightweight-ization -- the configuration, the production process, etc. Then, without receiving constraint of the quality of the material and others of a moving core, the purpose of this invention is [ for really joining a moving core to a valve stem ] cheap, and is to offer the approach of being suitable for mass production.
[0004]
[Means for Solving the Problem] This invention makes it a main point to complete sintering of a green compact, and junction to a valve stem at one process, when it is good and the powder of the ferromagnetic ingredient suitable for a moving core or the mixed powder of that presentation is pressed into the necessary geometry of a moving core, and elasticity magnetic properties insert this green compact in the position of a valve stem and sinter it. in this case -- as the ferromagnetic ingredient which suits an application -- electromagnetism, such as pure iron, a Fe-P system, a Fe-Si system, a Fe-Si-P system, a permalloy system, the Permendur system alloy, and SUS410, -- there is a stainless steel ingredient. Moreover, as for the ingredient of a valve stem, it is desirable that the permeability is 100 or less. Since the installation to a valve stem does not take a machining allowance by this approach, that part moving core can be formed into small lightweight.
[0005] When a moving core (green compact) is inserted in a valve stem and carries out sinter bonding to it, in order for the components obtained to have high bonding strength, it is necessary to aim at junction by solid phase diffusion of an alloy content by sintering in the mere mechanical condition that burned and inserted in and the plane of composition of both the members instead of **** fully stuck. And about this point, all the aforementioned ingredients below pure iron have the

amount of dimensional changes (the amount of expansion) smaller than the valve stem of ingot material in the pyrosphere (800 degrees C or more of abbreviation [ An iron system sintered alloy ]) which advances sintering so that it may explain later, and since sintering advances after the green compact has bound the valve stem tight, they are very convenient.

[0006] moreover, the time of inserting in both members -- inserting in -- suiting -- variation of tolerance (difference of the inside diameter of the hole of a green compact, and the outer-diameter dimension of a valve stem) -- being important -- the valve stem -- being thick (closing and inserting in) -- it is desirable to set up and to press fit in the hole of a green compact, and both degree of adhesion becomes high, so that an interference is large. However, in order to avoid breakage by the tensile stress of a green compact with low reinforcement, it is necessary to stop an interference within less than 30 micrometers and at most 60 micrometers preferably. Even when it passes and chooses eye **, a clearance is so good that it is small, and should be stopped to 5 micrometers or less.

[0007]

[Embodiment of the Invention] The condition of the thermal expansion by each heating is explained about the case where use stainless steel (SUS304) for valve-stem material, and the green compact (green density 7.0 g/cm3) of Fe-0.6P is first used for moving core material. SUS304 is making the Measuring condition lower [ green compact ] at the same rate, after carrying out the temperature up of the green compact to 1130 degrees C at the rate of 10 degrees C/m in nitrogen gas, respectively and holding it for 20 minutes in a vacuum. In addition, especially % about the presentation in this specification etc. is weight % unless it refuses.

[0008] Since SUS304 has already presented the austenite phase at the room temperature, the allotropic modification accompanying heating and cooling is not produced. If it is a dimensional change by mere heat, uniform expansion and contraction are shown along with rise and fall of temperature and it returns to a room temperature, a dimension will also return to the original dimension. On the other hand, in the case of Fe-0.6P green compact, it is the same as that of the case of ingot material, but the eburnation (contraction) by disappearance of pore-izing of the clearance between powder particles - pore is produced in the sintering process from a green compact as a phenomenon peculiar to a sintered alloy, and these contraction reduces the amount of expansion by heat. Consequently, the amount of thermal expansion of the green compact in the pyrosphere of 800 degrees C or more of abbreviation to which diffused junction advances becomes small far from SUS304, therefore when both are entrapped and are sintered, sintering in the condition of having stuck the moving core to the valve stem is ensured.

[0009] Next, after carrying out a temperature up and holding for 20 minutes to 1200 degrees C at the rate of 10 degrees C/m in a vacuum about the green compact (green density 7.1 g/cm3) of the permalloy (Fe-47nickel) which is similarly suitable for a moving core, the condition of the thermal expansion at the time of returning to ordinary temperature is explained at the same rate as compared with SUS304.

[0010] Although a permalloy green compact expands gently up to near 550 degree C of a temperature up process and the inclination of expansion becomes a little large after that, the amount of expansion is always smaller than SUS304. Above 1170 degrees C, contraction according [ temperature ] to sintering is observed and this contraction continues also in the maintenance phase of sintering temperature. And in the phase which returned to the room temperature, the permalloy sintered compact has contracted SUS304 rather than the green compact before heating as well as the case of Fe-0.6P to a dimension returning to the original dimension.

[0011] Therefore, the moving core which consists of said proper ferromagnetic ingredient with powder-metallurgy processing is pressed, if the green compact and valve stem of nonmagnetic material are inserted in and sintered, after the green compact has bound the valve stem tight, sintering can advance, and both can be unified firmly.

[0012] (Example 1) First, as an object for moving cores, to powder lubricant, the presentation used Accra wax (trade name) 0.5%, and produced the cylindrical green compact (the bore of 4mm, the outer diameter of 10mm, die length of 12mm, and green density 7.0 g/cm3) which is Fe-0.6P. Although the slot of several articles is established in the lengthwise direction as a path of a fluid at the periphery of this cylinder, that is not the summary of this invention. On the other hand, to the

valve stem, the valve stem with a diameter of 4mm was produced using nonmagnetic stainless steel SUS304. Next, the green compact was inserted in to the position of a valve stem by press fit of 20 micrometers of interferences, it sintered for 60 minutes at 1200 degrees C among the decomposition ammonia gas ambient atmosphere, and sintering of a moving core and junction to a valve stem were performed at one process.

[0013] When the breakdown test which fixes the moving core and extrudes a valve stem about this product was carried out, before the plane of composition broke, when the load amounted to 350kg, deformation of a valve stem was produced. This is because the bonding strength of both members surpassed the compression yield strength of a valve stem, and is estimated that junction sufficient as components of a solenoid valve was attained. Incidentally, although a moving core is conventionally closed to the circular sulcus established in the periphery of a valve stem, since the specification in that case is 180kg of loads-proof, the approach of this invention will have exceeded far.

[0014] (Example 2) The valve stem was the same as that of the case of an example 1, and changed the quality of the material of the green compact for moving cores into the permalloy (Fe-47nickel; green density 7.1 g/cm3). When both were entrapped by press fit of 20 micrometers of interferences, it sintered for 60 minutes at 1200 degrees C among the vacuum and the reinforcement of the obtained product was measured like the case of an example 1, the result was the same as the case of an example 1. Therefore, it is estimated that this has also reached junction sufficient as components of a solenoid valve.

[0015]

[Effect of the Invention] As explained in full detail above, unlike the conventional approach of fixing to a valve stem the moving core formed from ingot material by plastic working etc., according to this invention using a sintered alloy, a moving core can be conventionally formed into small lightweight, and the responsibility of a solenoid valve is improved. Since sintering of a moving core and junction to a valve stem are furthermore completed at one process, also economically, it excels.

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[Translation done.]